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(71)Applicant : NIPPON STEEL CORP
(72)Inventor : TANAKA MASAHIRO
HAGA HIROTSUGU
HASEBE MASAMI

(54) METHOD FOR CONTROLLING PULLING OF SINGLE CRYSTAL, PRODUCTION OF SINGLE CRYSTAL AND APPARATUS THEREFOR

(57)Abstract:
PROBLEM TO BE SOLVED: To enhance the rate of success in pulling a single crystal and to control the pull in such a manner that the single crystal having high quality is pulled up by measuring the two-dimensional temp. distribution and time fluctuation of a melt surface in single crystal production by a CZ method and adjusting the conditions of pulling up the single crystal.
SOLUTION: This control method comprises pulling the single crystal from the crystal member melt melted by a heater in a rotating crucible. The two-dimensional temp. distribution on the surface of the crystal member melt and the time fluctuation thereof are measured at the point of the time the seed crystal of the single crystal comes into contact with the melt surface or during the pulling up of the single crystal, by which the growth environment of the single crystal is recognized. The rotating speed of the crucible, the rotating speed of the single crystal, the relative positions of the crucible and a heater and the heating conditions for the heater are controlled in accordance with therewith, by which the temp. distribution of the melt surface is so controlled as to be axisymmetrically controlled. The temp. distribution near at least the crystal growth boundary is so controlled as to be approximated to the axisymmetry and the temp. fluctuation with the time is so controlled as to be lessened.

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CLAIMS

[Claim(s)]
[Claim 1] It is the single crystal raising control approach of pulling up a single crystal from the crystal member melt by which is in the rotating crucible and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising By getting to know the growth environment of this single crystal, and adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, and the heating conditions of this heater based on this The single crystal raising control approach that raising success percentage of this single crystal is characterized by making this single crystal into high quality highly by making the temperature distribution on this front face of melt into axial symmetry.
[Claim 2] It is the single crystal raising control approach of pulling up a single crystal from the crystal member melt by which is in the rotating crucible and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising By getting to know the growth environment of this single crystal, and adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, and the heating conditions of this heater based on this the temperature distribution near the crystal growth interface are brought close to axial symmetry at least -- and -- or the single crystal raising control approach characterized by making temperature fluctuation of time amount small and the raising success percentage of this single crystal making this single crystal high quality highly.
[Claim 3] It is the single crystal raising control approach of pulling up a single crystal while impressing a level magnetic field to the crystal member melt by which is in the rotating crucible and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising The non-axial symmetry degree of the non-axial symmetry temperature distribution on this melt front face inevitably produced in level magnetic field impression is got to know. Non-axial symmetry temperature distribution by bringing close to axial symmetry by adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, the heating conditions of this heater, and this level magnetic field intensity based on this The single crystal raising control approach characterized by the raising success percentage of this single crystal making this single crystal high quality highly.
[Claim 4] It is the single crystal raising control approach of pulling up a single crystal while impressing a level magnetic field to the silicon melt by which is in the rotating quartz crucible and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising The single crystal raising control approach characterized by controlling the oxygen density in a single crystal by getting to know the growth environment of this single crystal, and adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, the heating conditions of this heater, and this level magnetic field intensity based on this.
[Claim 5] The single crystal manufacture approach which is the single crystal manufacture approach of pulling up a single crystal from melt, and is characterized by grasping the optimal crystal growth environment by

measuring the secondary temperature distribution on this front face of melt, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising.
[Claim 6] The single crystal manufacture approach which is the single crystal manufacture approach of pulling up a single crystal from melt, and is characterized by grasping the optimal crystal growth environment and raising the single crystal raising success percentage of this single crystal by measuring the secondary temperature distribution on this front face of melt, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising.
[Claim 7] The single crystal manufacture approach which is the single crystal manufacture approach of pulling up a single crystal from melt, and is characterized by grasping the optimal crystal growth environment, making it contrast with this manufactured single crystal quality, and obtaining a quality single crystal by measuring the secondary temperature distribution on this front face of melt, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising.
[Claim 8] It is the single crystal manufacture approach of pulling up a single crystal from the crystal member melt by which is in the rotating crucible and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or single crystal raising By getting to know the growth environment of this single crystal, and adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, and the heating conditions of this heater based on this The single crystal manufacture approach characterized by this thing to which the single crystal raising success percentage of this single crystal becomes it is high and quality [this single crystal], and that it is melt-skin-temperature-distributed, and it reaches or is brought close to the time variation of skin temperature.
[Claim 9] The single crystal manufacturing installation characterized by having a 2-dimensional temperature-distribution measurement means on the front face of melt which is the single crystal manufacturing installation which pulls up a single crystal from melt, and was installed in the melt upper part, and the time variation measurement means and crystal growth environmental control means of melt skin temperature.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the single crystal manufacture approaches that single crystal raising success percentage is high and, such as quality silicon, the single crystal raising control approach, the single crystal manufacture approach, and its equipment.
[0002]
[Description of the Prior Art] The Czochrlski method (it is described as a CZ process below) pulled up as the single crystal manufacture approach, growing up a crystal from the melt in a crucible is performed widely. When it is going to obtain a single crystal by this CZ process, the single crystal manufacturing installation of a configuration as typically shown in drawing 1 is used. In such a single crystal manufacture approach, a raw material is first paid in the crucible in drawing, and this raw material is dissolved at the heater which encloses them.
[0003] And seed crystal is taken down and a melt front face is made to contact from the upper part of the melt in this crucible. The single crystal of a predetermined path is produced by pulling up up, controlling a raising rate, rotating this seed crystal. In this crystal raising, polycrystal-izing of a crystal, and in order to prevent deformation, melt floating has been controlled for the dopant in a crystal, the object which controls concentration distribution of an impurity.
[0004] In the former, there is no method of investigating this melt floating directly, operating conditions, such as crucible rotational speed, a crystal rotation rate, a relative location of a crucible and a heater, and heating conditions of a heater, were adjusted by trial and error, and the optimal operation environment has been acquired for crystal growth. Furthermore, as an auxiliary means which gets to know whether the crystal growth environment stable otherwise is realized, there was a method of controlling the convection current by impressing a level magnetic field to melt, or pressing down an oscillation of a melt front face as stated to JP,58-50951,B. Also in this case, in order to acquire the optimal crystal growth environment, the condition retrieval by trial-and-error was required.
[0005] Moreover, there was the approach of measuring the temperature of one point with a melt front face as an auxiliary means which gets to know whether the optimal crystal growth environment is realized, and making obtained melt skin temperature fluctuation the index of the optimal crystal growth environment. For example, as the outline was shown in drawing 2 , the radiation thermometer was attached in the chamber upper part, and the temperature of one point on the front face of melt was measured. The operating condition was controlled by the measurement so that temperature fluctuation became to some extent small.
[0006] Furthermore, in the Japanese-Patent-Application-No. No. 53190 [61 to] official report, a crystal-melt boundary is got to know with a CCD camera using the difference of the emissivity of a crystal and melt, the temperature gradient of the direction of a path by the side of the melt is measured, and the approach of controlling crystal growth by controlling a raising rate, a crucible and a crystal rotation rate, and melt temperature is reported.
[0007]
[Problem(s) to be Solved by the Invention] However, many time amount and efforts are required for retrieval of the optimal operating condition by the above trial-and-error. Moreover, these conditions will change with aging, such as a carbon member in a raising furnace. Considering as the guide of stable crystal growth only by the temperature measurement of one point which furthermore has a melt front face by the radiation thermometer

has a problem in respect of the following.
[0008] Conventionally, to the revolving shaft of a crucible, the temperature distribution of the melt in a crucible are axial symmetry, and have been considered to be steady. however -- according to research of the latest this invention person -- operating conditions, such as crucible rotational speed, -- whenever [melt internal temperature] -- distribution -- non-axial symmetry -- it is -- un--- a law -- it became clear that it may become a **. this -- un--- a law -- a part with low temperature and a high part are made to the circumferencial direction of melt according to temperature distribution symmetrical with a ** and a non-shaft, and temperature fluctuation exists in the circumferencial direction on a crystal growth interface. Furthermore, in order that this low-temperature section and the temperature fall section may move to a crucible hand of cut, temperature fluctuation arises also in the location fixed on the crystal growth interface.
[0009] When temperature fluctuation of the melt near the crystal growth interface is large, a crystal polycrystal-izes, nonuniformity arises to the impurity with which it is incorporated by the crystal, or the defective concentration in a crystal increases. The magnitude of this temperature fluctuation changes with locations of the melt to measure. That is, a really stable crystal growth environment cannot be known in having measured only one point which has a melt front face like the former.
[0010] Furthermore, the temperature gradients of the direction of a path in a melt front face are also the important conditions which should be controlled. the shoulder of a crystal -- being large -- when a temperature gradient radial [in a melt front face] is extremely small, the diameter of a crystal may become large suddenly and may sometimes polycrystal-ize Moreover, when a radial temperature gradient is extremely small, a crystal may deform greatly at the time of growth of the body section of a crystal, and the yield and productivity of a crystal are spoiled at it. The temperature gradient of the direction of a path in this melt front face was not able to be observed by the measurement of one point on the conventional front face of melt.
[0011] The following three approaches were reported by making this melt floating into the approach of investigating directly recently.
[0012] (1) How (4 Yamagishi, Fusegawa: Japanese crystal growth institute magazine VOL17, No3& 1990) to expect floating on the front face of melt from a striped pattern with the black melt front face seen at the time of raising.
[0013] (2) How (Shiroishi: collection 1st separate volume of 93 spring Japan Society of Applied Physics drafts 1 a-H6) to float a marker on a melt front face and to expect floating on the front face of melt from a motion of the marker.
[0014] (3) How (KKakimoto, M.Eguti, H.watanabe, J Crystal Grouth 88 (1988) 365) to put the marker of the almost same consistency as the melt into melt, to apply an X-ray to the whole melt, to follow a motion of a marker according to the difference of the rate of radioparency of melt and a marker, and to get to know floating of the whole melt.
[0015] However, still by the approach of getting to know melt floating from a striped pattern with a black melt front face, the relation between a striped pattern and melt floating is not clear. Moreover, by the approach of putting in a marker in melt and getting to know melt floating, crystal growth becomes impossible. Thus, in order to use it in a actual single crystal manufacture site, there is a problem in these approaches.
[0016] Moreover, only temperature-distribution control of the radial single dimension in a melt front face is indicated by JP,61-53190,A.
[0017] In the single crystal growth by the CZ process, melt floating at the time of contacting melt floating and the initial state of temperature distribution, i.e., seed crystal, to melt and temperature distribution are dramatically more important still for subsequent crystal growth. In the single crystal growth by the CZ process, there are control means, such as a raising rate, a crucible revolution, a crystal revolution, and heater power, and feedback control which changed these into crystal growth also actually is performed. However, these control is restricted by the initial condition of melt floating and temperature distribution.
[0018] That is, if initial condition is bad, however it may correct by the above-mentioned control means during crystal raising, there is a limitation.
[0019] grasping promptly the two-dimensional temperature distribution on the front face of melt, and its time variation in a detail according to non-contact in this invention during the event of contacting seed crystal to melt, or single crystal raising -- the initial condition of crystal growth -- the optimal -- carrying out -- and -- or it aims at maintaining the optimal raising environment also during crystal raising.

[0020] This invention is applicable to all the crystals that can be pulled up by the CZ process. And it is effective in crystal raising of the silicon single crystal with which especially enlargement of a crystal is progressing.
[0021]
[Means for Solving the Problem] In order to attain the above-mentioned object, this invention persons observe a melt front face two-dimensional, are grasping the time variation of melt skin temperature in a detail, find out the approach of raising a quality single crystal to stability, and come to complete this invention.
[0022] Namely, it is the single crystal raising control approach of pulling up a single crystal from the crystal member melt by which this invention has in the rotating crucible and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising By getting to know the growth environment of this single crystal, and adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, and the heating conditions of this heater based on this By making the temperature distribution on this front face of melt into axial symmetry, the raising success percentage of this single crystal is the single crystal raising control approach characterized by making this single crystal into high quality highly.
[0023] Moreover, it is the single crystal raising control approach of pulling up a single crystal from the crystal member melt by which this invention has in the rotating crucible and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising By getting to know the growth environment of this single crystal, and adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, and the heating conditions of this heater based on this the temperature distribution near the crystal growth interface are brought close to axial symmetry at least -- and -- or it is the single crystal raising control approach which makes temperature fluctuation of time amount small and is characterized by the raising success percentage of this single crystal making this single crystal high quality highly.
[0024] Moreover, it is the single crystal raising control approach of pulling up a single crystal while impressing a level magnetic field to the crystal member melt by which this invention has in the rotating crucible and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising The non-axial symmetry degree of the non-axial symmetry temperature distribution on this melt front face inevitably produced in level magnetic field impression is got to know. Non-axial symmetry temperature distribution by bringing close to axial symmetry by adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, the heating conditions of this heater, and this level magnetic field intensity based on this The raising success percentage of this single crystal is the single crystal raising control approach characterized by making this single crystal into high quality highly.
[0025] Moreover, it is the single crystal raising control approach of pulling up a single crystal while impressing a level magnetic field to the silicon melt by which this invention has in the rotating quartz crucible, and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising By getting to know the growth environment of this single crystal, and adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, the heating conditions of this heater, and this level magnetic field intensity based on this It is the single crystal raising control approach characterized by controlling the oxygen density in a single crystal.
[0026] Moreover, it is the single crystal manufacture approach of pulling up a single crystal from melt, and this invention is measuring the secondary temperature distribution on this front face of melt, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising, and is the single crystal manufacture approach characterized by grasping the optimal crystal growth environment.
[0027] Moreover, this invention is the single crystal manufacture approach of pulling up a single crystal from melt, and is the single crystal manufacture approach characterized by being measuring the secondary

temperature distribution on this front face of melt, and its time variation, grasping the optimal crystal growth environment, and raising the single crystal raising success percentage of this single crystal during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising.

[0028] Moreover, this invention is the single crystal manufacture approach of pulling up a single crystal from melt, is measuring the secondary temperature distribution on this front face of melt, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or this single crystal raising, and is the single crystal manufacture approach characterized by grasping the optimal crystal growth environment, making it contrast with this manufactured single crystal quality, and obtaining a quality single crystal.

[0029] Moreover, it is the single crystal manufacture approach of pulling up a single crystal from the crystal member melt by which this invention has in the rotating crucible and melting was carried out at the heater. By measuring the two-dimensional temperature distribution of this crystal member melt front face, and its time variation during the event of contacting this melt front face in the seed crystal of this single crystal, or single crystal raising By getting to know the growth environment of this single crystal, and adjusting the rotational speed of this crucible, this single crystal rotational speed, the relative location of this crucible and this heater, and the heating conditions of this heater based on this It is the single crystal manufacture approach characterized by this thing to which the single crystal raising success percentage of this single crystal becomes it is high and quality [this single crystal], and that it is melt-skin-temperature-distributed, and it reaches or is brought close to the time variation of skin temperature.

[0030] Moreover, this invention is a single crystal manufacturing installation which pulls up a single crystal from melt, and is a single crystal manufacturing installation characterized by having a 2-dimensional temperature-distribution measurement means on the front face of melt installed in the melt upper part, and the time variation measurement means and crystal growth environmental control means of melt skin temperature.

[0031] A crystal growth environment means temperature, the rate of flow, and the distribution and time variation of each high impurity concentration in the interior of melt, a melt front face, a melt-crystal interface, and a melt-crucible interface here. Moreover, single crystal raising success percentage means M/N, if the count which is a single crystal is made into M times covering a total crystal overall length when N time crystal is pulled up. Moreover, it is a non-rearrangement single crystal, and high impurity concentration (a dopant, oxygen density, etc.) and distribution of those are controlled, and there is no crystal defect concentration, such as OSF (Oxidation-induced Stacking Fault), or a high quality crystal has it, and means the crystal by which oxygen sludge concentration distribution was controlled. [dramatically small] Moreover, although a low-temperature field becomes the temperature distribution of an ellipse form mostly on breadth and a melt front face in the direction of a magnetic field when a horizontal magnetic field is impressed to melt, the ratio of lay length vertical to the magnetic field to the direction of a magnetic field of the ellipse temperature distribution is meant as a non-axial symmetry degree.

[0032] By this invention, by observing melt skin temperature two-dimensional using single crystal raising melt information, a crystal growth environment can be grasped in a detail and the operation guide for acquiring the optimal environment for crystal growth can be created easily.

[0033] Moreover, the optimal temperature conditions for crystal growth, a melt plastic flow condition, and oxygen density conditions are realizable by grasping a crystal growth environment in a detail and controlling crucible rotational speed, single crystal rotational speed, the relative location of a crucible and a heater, the heating conditions of a heater, and level magnetic field intensity by this invention based on this by observing melt skin temperature two-dimensional using single crystal raising melt information.

[0034] It is the monochromatic radiation reinforcement Ib of the following blackbody given with the principle of Planck from a melt front face in single crystal raising. The radiant ray of the reinforcement I to which the emissivity epsilon of melt was applied is injected.

[0035] I=epsilonInu Ib =2C1/(lambda 5 {exp(C2 / lambdaT)-1})

Here, lambda is wavelength and T is temperature, C1, and C2. It is the 1st and 2nd constant of Planck. Melt skin temperature can be known by non-contact by measuring this radiation reinforcement two-dimensional from the melt upper part, and changing it into temperature according to the transformation corrected so that a system more nearly actual than the above-mentioned conversion or ****** might be suited.

[0036] The time variation of melt skin temperature can be known two-dimensional by observing these

continuously. Since the 2-dimensional temperature on this front face of melt is reflecting melt floating, it can know the flow of the whole melt from 2-dimensional temperature distribution. And melt floating can change by changing the heating conditions of crucible rotational speed, a crystal rotation rate, a crucible, and a heater, and this melt skin temperature distribution and temperature fluctuation can be changed. Therefore, these melt surface data serves as an operation guide for obtaining the optimal operating condition for crystal growth.
[0037] Since melt skin temperature is always observed and an operating condition can be amended the optimal even if the member of a furnace carries out aging, there is an advantage that the operation in consideration of aging is possible in the approach described above.
[0038] The melt warmed by the crucible side attachment wall goes up in accordance with a crucible side attachment wall, and the description of melt floating in CZ raising changes the flow direction in the direction of a crucible medial axis near the free surface. And after sinking near a medial axis, the sense is changed at a crucible bottom and it flows toward a crucible side attachment wall. The flow (meridional flow) in the vertical section of drawing 3 (a) is formed by this. Usually, a crucible is rotated in CZ raising. Thereby, the flow induction is carried out [flow] to the above-mentioned flow by crucible revolution laps. Thus, density stratification (condition that the consistency difference exists in a fluid) is carried out, and in the revolving fluid, revolution stratified fluid, a call, and its typical example are the atmospheric air of the earth, and melt floating in CZ raising and floating of the atmospheric air of the earth are very well alike.
[0039] Side ****** and numerical floating simulation of this invention person in such revolution stratified fluid showed the following things. The effectiveness of the crucible revolution to revolution stratified fluid is described using drawing 3 below. The magnitude of the rotational frequency of a low crucible revolution, an inside crucible revolution, a high crucible revolution, because a relative crucible is shown among drawing. Since the flow of revolution stratified fluid changes with heating conditions etc. besides the number of crucible revolutions, it is not decided only by the number of crucible revolutions.
[0040] When the crucible revolution of a revolution laminar-flow object is a low revolution, flow is almost axial symmetry-flow and melt skin temperature distribution is also axial symmetry mostly (drawing 3 (A)). However, if crucible rotational speed is enlarged, flow will change to non-axial symmetry (drawing 3 (B)). Thereby, the temperature distribution on the front face of melt also become non-axial symmetry. And this non-axial symmetry distribution moves to a crucible hand of cut at the rate depending on crucible rotational speed. When its attention is paid to one on the periphery of a fixed path with a melt front face, since the melt of low temperature and the melt of high temperature come to that point periodically or unsteadily, at that point, the temperature fluctuation based on the temperature gradient of the melt of low temperature and an elevated temperature arises by the rotation of temperature distribution symmetrical with this non-shaft. The path location where the magnitude and the period of this temperature fluctuation have the greatest temperature fluctuation amplitude on a melt front face in things in the path location to which its attention is paid exists.
[0041] The path location which furthermore has this greatest temperature fluctuation amplitude changes with operating conditions, such as crucible rotational speed. In (a) in drawing 3 (B), and (b), the law of (b) has a relatively large crucible rotational frequency. In the condition of (b) of drawing 3 (B), even if it is the same non-axial symmetry temperature distribution, the small field of temperature fluctuation is formed near the medial axis. That is, the greatest part of temperature fluctuation moves to the direction more near a crucible wall compared with (a) of drawing 3 (B). If the crucible revolution is enlarged further, the temperature distribution in the flow in a vertical section and a horizontal section will become like drawing 3 (C).
[0042] The temperature distribution in a melt front face serve as the cellular structure, and temperature fluctuation arises because this cel moves to a circumferencial direction. This temperature fluctuation is smaller than an inside crucible revolution field. Thus, observing melt skin temperature distribution, operating conditions, such as crucible rotational speed, a crystal rotation rate, a crucible location, and heater heating conditions, can be changed, and temperature distribution and temperature fluctuation in a melt front face can be controlled.
[0043] Moreover, the temperature gradient of this direction of a path can also change operating conditions, such as crucible rotational speed, a crystal rotation rate, a crucible location, and heater heating conditions, and can be controlled under the condition that the temperature gradient of the direction of a path in a melt front face can also be grasped by observing a melt front face two-dimensional.
[0044] In temperature measurement only by one on the front face of melt, it is difficult to have stated above.

[0045] Furthermore, when growing up a silicon single crystal from a quartz crucible, the oxygen density in a silicon single crystal also changes with change of such a melt floating pattern. The oxygen which melted and came out of the quartz crucible is carried to a melt front face and a crystal growth interface by flow. A part is incorporated by the crystal although most of these oxygen evaporates from a melt front face. Case [whose flow is / like drawing 3 (A)], the oxygen which melted and came out of the crucible is attained to a crystal growth interface, after the most passes along a melt front face. The oxygen density in the melt in the crystal growth interface at that time is low by evaporation of the oxygen from a melt front face. That is, by flow like drawing 3 (A), the oxygen density under crystal becomes low.
[0046] In the melt floating pattern with which the boiling style exists like drawing 3 (C) on the other hand, the oxygen which melted and came out of the quartz crucible reaches a direct crystal growth interface, without passing along a melt front face. In this case, since evaporation of the oxygen from a melt front face does not take place, the oxygen density in the melt which reached the crystal growth interface is high. That is, the oxygen density under crystal becomes high. Thus, the oxygen density of a single crystal can be expected by getting to know a melt floating pattern from a melt front face. And it becomes possible to change operating conditions, such as crucible rotational speed, a crystal rotation rate, a crucible location, and heater heating conditions, and to control the oxygen density under crystal.
[0047] In this invention, the 2-dimensional temperature distribution in a melt front face are acquired by observing 2-dimensional distribution of the radiant energy emitted from a melt front face with imaging devices, such as a CCD camera, changing into an electrical signal, and changing it into temperature. Projecting these 2-dimensional temperature distribution on a display, during operation, operating conditions, such as crucible rotational speed, a crystal rotation rate, a crucible location, and heater heating conditions, can be changed, and the optimal condition for crystal raising can be acquired easily.
[0048]
[Embodiment of the Invention] This invention is applicable to all the crystals that can be pulled up by the CZ process. And it is effective in crystal raising of the silicon single crystal with which especially enlargement of a crystal is progressing.
[0049] Hereafter, the example of silicon raising explains this invention concretely.
[0050] As shown in drawing 4 , melt skin temperature distribution in the condition that there is no crystal was measured two-dimensional from the chamber upper part of the melt upper part with the CCD camera. After dissolving 45kg polycrystalline silicon in a 18 inch crucible to drawing 5 , the mimetic diagram of the skin temperature distribution when observing a melt front face by the above-mentioned approach from the upper part is shown. In addition, a drawing middle point line expresses the location equivalent to the crystal edge of a 6 inch crystal. The temperature distribution in crucible rotational-speed 2rpm are shown in drawing 5 (a). The temperature distribution in crucible rotational-speed 5rpm are shown in drawing 5 (b).
[0051] The temperature distribution on the front face of melt had already changed on the unsymmetrical shaft in crucible rotational-speed 2rpm, and this was rotating to the crucible hand of cut. The largest place of this non-axial symmetry nature existed in around the edge of a 6 inch crystal exactly from the crucible core (drawing 5 (a)). Moreover, the temperature gradient of the direction of a path on the front face of melt had also taken the minimum value in the largest location of temperature fluctuation. the result of having pulled up the 6 inch crystal in this condition -- the shoulder of a crystal -- being large -- almost all crystals polycrystal-ized in the process. The single crystal raising success percentage in this case was 10%.
[0052] On the other hand, although the temperature distribution on the front face of melt show unsymmetrical axial also in the state of drawing 5 (b), by having gathered crucible rotational speed, the smallest part of the temperature gradient of the largest part and the direction of a path of the temperature fluctuation on a melt front face is moving outside a value at least in the crystal edge of a 6 inch crystal, and has become axial symmetry temperature distribution mostly focusing on melt. When the 6 inch crystal was grown up in such an environment, a crystal carries out neither polycrystal-izing nor deformation, but had been lengthened by most with the single crystal. The single crystal raising success percentage in this case was 98%.
[0053] Next, the single crystal Czochralski method which impressed the horizontal magnetic field is described.
[0054] After dissolving 45kg polycrystalline silicon in drawing 6 into a 18 inch crucible, the mimetic diagram of the skin temperature distribution when observing the melt front face when impressing a horizontal magnetic field is shown. In addition, a drawing middle point line expresses the location equivalent to a 6 inches crystal

edge. The temperature distribution in crucible rotational-speed 1rpm and the magnetic field intensity (G) of 3000 gauss are shown in drawing 6 (a). Rotational-speed 8rpm and the temperature distribution in magnetic-field-intensity 5000G are shown in drawing 6 (b). The temperature distribution on the front face of melt spread to a low-temperature field in the direction of a magnetic field by impressing a horizontal magnetic field.
[0055] The ratio of lay length vertical to a magnetic field to the direction of a magnetic field of the low-temperature field of drawing 6 is meant as the unsymmetrical shaft degree stated to claim 3. This low-temperature field is standing it still without rotating. This unsymmetrical shaft degree of a perpendicular direction / direction of magnetic field =0.6) was [the drawing 6 (a) (magnetic field] larger than a perpendicular direction / direction of magnetic field =0.9) to the drawing 6 (b) (magnetic field. The crystal grew up to be stability when the crystal was grown up on condition that drawing 6 R> 6 (a) (97% of single crystal raising success percentage). the place into which the crystal was grown up on condition that drawing 6 R> 6 (b) on the other hand -- the shoulder of a crystal -- being large -- almost has sometimes been polycrystal-ized (8% of single crystal raising success percentage).
[0056] Next, the oxygen density control in silicon single crystal raising is described. After dissolving 45kg polycrystalline silicon in drawing 7 into a 18 inch crucible, on a melt front face, the mimetic diagram of the skin temperature distribution when observing a melt front face is shown by the above-mentioned approach from the upper part. In addition, a drawing middle point line expresses the location equivalent to the crystal edge of a 6 inches crystal. The temperature distribution in crucible rotational-speed 5rpm are shown in drawing 7 at (a). The temperature distribution in crucible rotational-speed 8rpm are shown in drawing 5 (b). If it sees on the whole at the time of crucible rotational-speed 5rpm, although temperature distribution are unsymmetrical shafts, they are unsymmetrical shafts mostly near the melt core.
[0057] On the other hand, by crucible rotational-speed 8rpm, the boiling style from a crucible bottom occurs and cel-like temperature distribution are shown. When the 6 inch crystal was pulled up on two condition from now on, each average oxygen density became 10.0x1017 atms/cm3 (JEIDA) at the time of 8.5x1017 atms/cm3 (JEIDA) and crucible rotational-speed 8rpm at the time of crucible rotational-speed 5rpm. That is, the oxygen density was able to be changed by controlling the cel-like temperature distribution on the front face of melt.
[0058]
[Effect of the Invention] As stated above, by the single crystal raising control approach of this invention claim 1 publication, by adjusting a crucible engine speed, single crystal rotational speed, the relative location of a crucible and a heater, and the heating conditions of a heater, the temperature distribution on the front face of melt can be made into axial symmetry, and the single crystal raising success percentage of a single crystal can make a single crystal high quality highly.
[0059] By the single crystal raising control approach of this invention according to claim 2, by adjusting crucible rotational speed, single crystal rotational speed, the relative location of a crucible and a heater, and the heating conditions of a heater, temperature fluctuation near the crystal growth interface can be made small at least, and the single crystal raising success percentage of a single crystal can make a single crystal high quality highly.
[0060] The single crystal raising success percentage of a single crystal can make a single crystal high quality highly by bringing non-axial symmetry temperature distribution close to axial symmetry by getting to know the non-axial symmetry degree of the non-axial symmetry temperature distribution on the melt front face inevitably produced in level magnetic field impression, and adjusting crucible rotational speed, single crystal rotational speed, the relative location of a crucible and a heater, the heating conditions of a heater, and level magnetic field intensity based on this by the single crystal raising control approach of this invention according to claim 3.
[0061] An oxygen density is controllable by the single crystal raising control approach of this invention according to claim 4 by adjusting crucible rotational speed, single crystal rotational speed, the relative location of a crucible and a heater, the heating conditions of a heater, and level magnetic field intensity.
[0062] By this invention according to claim 5, the temperature environment on the front face of melt can be grasped more certainly than one-point measurement of the conventional melt skin temperature, and it can consider as the operation guide which realizes the optimal temperature conditions for crystal growth, a melt plastic flow condition, and oxygen density conditions.
[0063] By the single crystal manufacture approach of this invention according to claim 6, the optimal crystal growth environment can be grasped and the single crystal raising success percentage of this single crystal can

be raised.
[0064] By the single crystal manufacture approach of this invention according to claim 7, the optimal crystal growth environment can be grasped, can be made to be able to contrast with this manufactured single crystal quality, and a quality single crystal can be obtained.
[0065] By the single crystal ****** approach of this invention according to claim 8, by adjusting crucible rotational speed, single crystal rotational speed, the relative location of a crucible and a heater, and the heating conditions of a heater, the single crystal raising success percentage of a single crystal becomes it is high and quality [a single crystal], and it is melt-skin-temperature-distributed, and it can reach or can bring close to the time variation of skin temperature.
[0066] By the single crystal manufacturing installation of this invention according to claim 9, from one-point measurement of the conventional melt skin temperature, the temperature environment on the front face of melt can be grasped certainly, and the optimal temperature conditions for crystal growth, a melt plastic flow condition, and oxygen density conditions can be realized.

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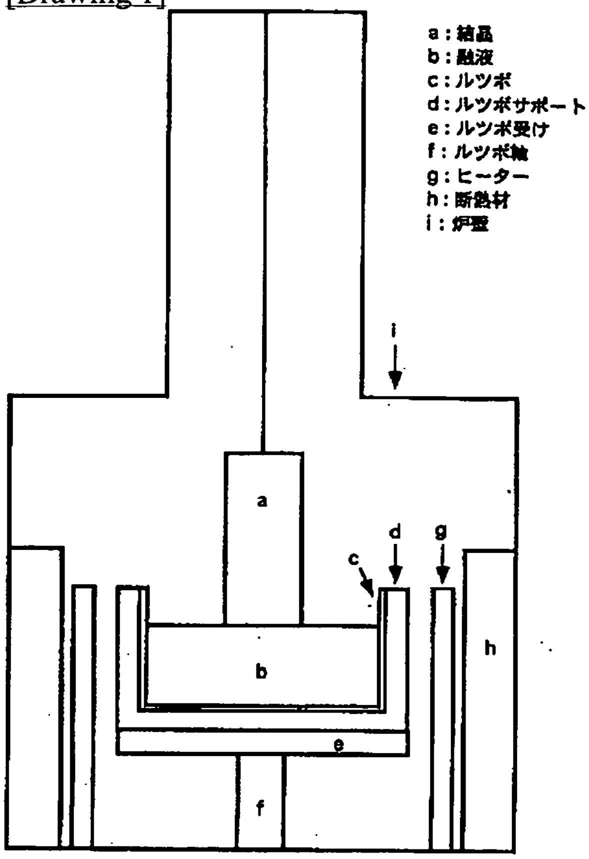
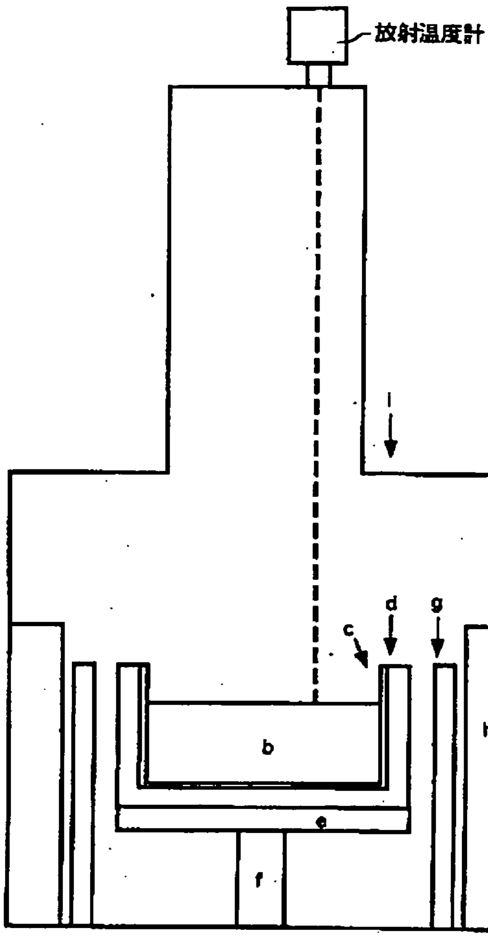
DRAWINGS

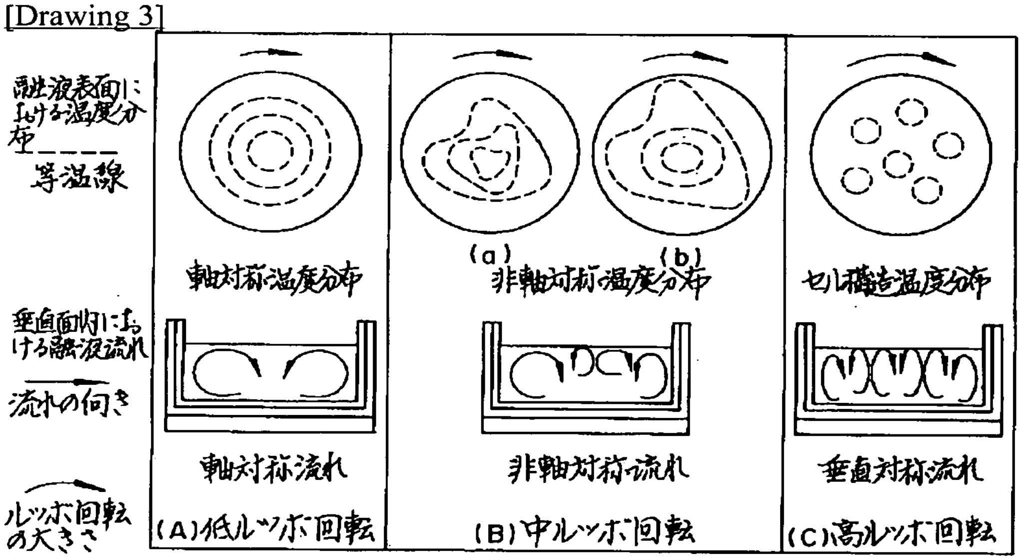
[Drawing 1]



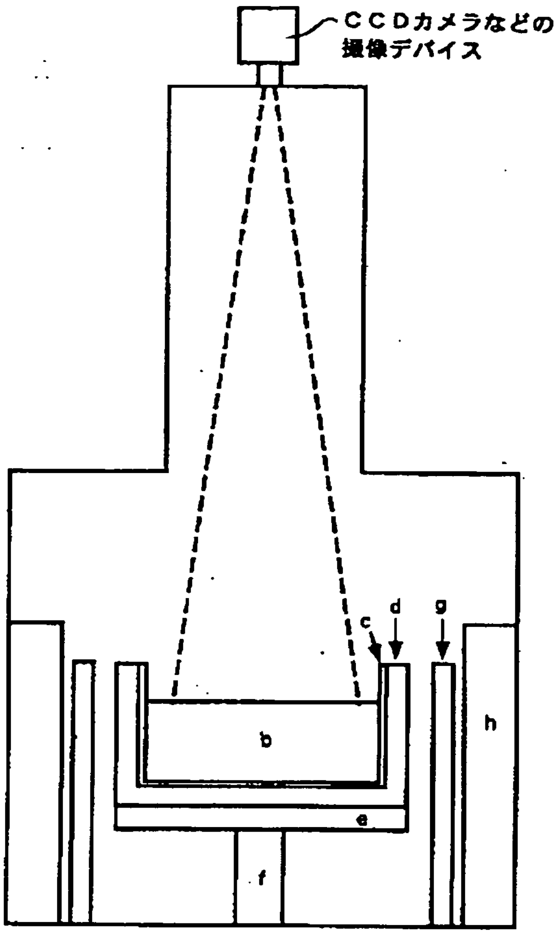
[Drawing 2]



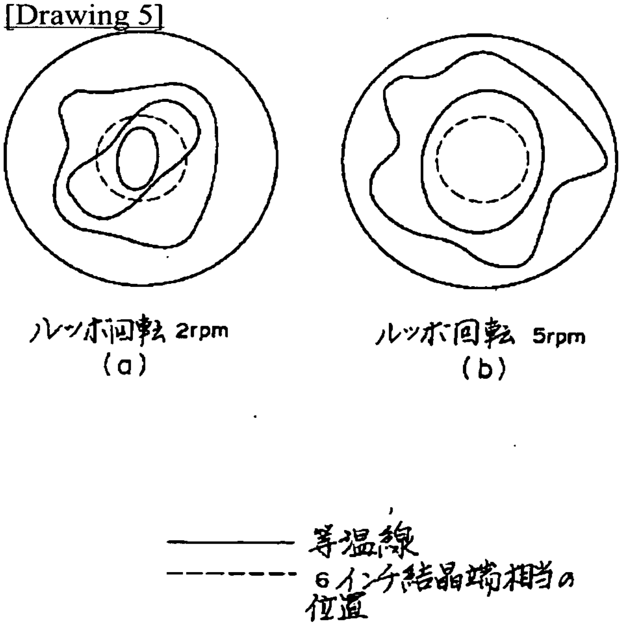
[Drawing 3]



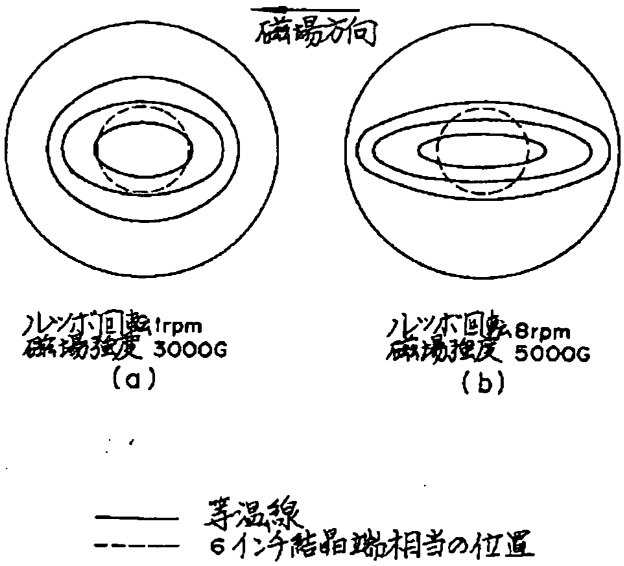
[Drawing 4]



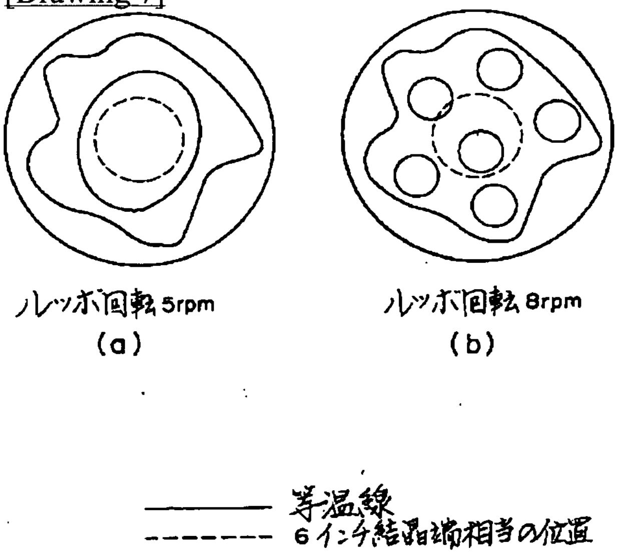
[Drawing 5]



[Drawing 6]



[Drawing 7]



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